QUARTERLY PROGRAM REPORT 64-2

PROJECT A-588

DEVELOPMENT OF NEW METHODS AND APPLICATIONS OF ANALOG COMPUTATION

F. Dixon and J. L. Hammond, Jr.

Contract NAS8-2473

12 March to 12 June 1964

Prepared for

GEORGE C. MARSHALL SPACE FLIGHT CENTER
National Aeronautics and Space Administration
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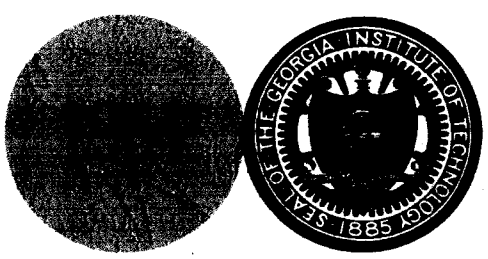

Engineering Experiment Station
GEORGIA INSTITUTE OF TECHNOLOGY
Atlanta, Georgia

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INTRODUCTION

Program Outline

Georgia Tech Research Project No. A-588 was established under Contract NAS8-2473 on 12 September 1961 in the Special Problems Branch of the Engineering Experiment Station's Physical Sciences Division. The overall project aim has been to assist the Flight Simulation Branch of the Computation Division at George C. Marshall Space Flight Center (MSFC) in the investigation and development of new methods and applications of analog computation within several areas of mutual interest. By agreement with the Contracting Officer's Representative, Dr. W. K. Polstorff of MSFC, efforts during the first year were devoted to 1) design and construction of an experimental electronic generalized integrator for potential application as an analog computing component, and 2) investigation of analog techniques for the generation of nonstationary noise voltages to be used in Monte Carlo studies. Results of these efforts are documented in the initial Annual Technical Summary (Report A588/P4) and in Technical Note No. 1 (Report A588/T1), both dated 12 November 1962.

Following a no-cost extension of the program until 12 November 1962, the contract was renewed for an additional twelve months to cover a) continued experimentation with the generalized integrator, and b) assistance to MSFC on problems connected with manned space flight simulation. After a further no-cost extension until 12 December 1963, the contract was renewed for another twelve months with the Scope of Work revised to read as follows.

A. Simulation of Manned Space Flight. The Contractor will continue the work already started under Contract NAS8-2473.

B. The Contractor will in consideration of work done with the generalized integration concentrate on an investigation and on improvement of electronic switches for analog computation, which are the key elements of the generalized integrator as well as of the analog incremental converter and of dual time scale analog computation.

C. Analytical investigations of methods for generating nonstationary noise of specified spectral and amplitude distribution for Monte Carlo simulation studies.

Project Organization

The first two of the above assigned tasks are being performed in the Special Problems Branch proper, which now has its Headquarters and Instrumentation Laboratory located in the new Nuclear Research Center (at 6th

Street and Atlantic Drive, N.W.) on the Georgia Tech campus. The third task is being performed largely by personnel associated with the School of Electrical Engineering, and utilizes facilities of the main Analog Computer Laboratory which is operated by the Special Problems Branch in the E.E. Building.

For purposes of administrative convenience, the project staff has been divided into two functional groups, presently organized as follows:

Group 1 - Tasks A and B (Instrumentation Lab)

Mr. Frederick Dixon (Senior Research Physicist) - Project Director

Mr. Frank R. Williamson (Assistant Research Engineer)

Mr. John W. Robertson (Reasearch Assistant)

Group 2 - Task C (School of E.E. and Analog Computer Lab)

Dr. Joseph L. Hammond, Jr. (Associate Professor) - Group Coordinator

Dr. Roger P. Webb (Assistant Professor)

Dr. Thomas M. White (Associate Professor)

Mr. Clifford O. Guffee (Graduate Teaching Assistant)

Mr. Richard E. Bryan (Graduate Research Assistant)

Progress reports for the two groups will normally be presented in separate sections of each Quarterly Program Report.

Conferences

Dr. W. K. Polstorff visited Georgia Tech on 17 April for a program planning conference with each of the Project A-588 groups.

F. R. Williamson, Jr. (Group 1) and J. L. Hammond, T. M. White, and R. E. Bryan (Group 2) visited Marshall Space Flight Center on 5 June to attend technical sessions of the Southeastern Simulation Council and hold supplementary project discussions with Dr. Polstorff and other personnel at the MSFC Flight Simulation Branch. During the morning meeting of the Simulation Council, Mr. Bryan presented a paper entitled "Generation of Non-Stationary Stochastic Processes," covering several aspects of the work performed under Task C of the contract.

GROUP 1 PROGRESS REPORT

Simulation of Manned Space Flight

There are no active assignments under Task A of the contract program at the present time.

Electronic Switches for Analog Computation

Literature Survey

A review has been made of all issues of the Defense Documentation Center (DDC) Technical Abstract Bulletins (TAB's) since 1 January 1963 for research reports of possible interest on electronic switching techniques and applications. Seven items uncovered from this source are being procured through the Georgia Tech Library. An additional 13 items (listed in the "limited distribution" section of the TAB's) have been identified for preliminary evaluation by the Project Officer at MSFC.

A review has been made of The Engineering Index for the years 1961 and 1962. The following pertinent articles have thus far been uncovered from this and other references to the open literature:

(1) Bell, B., and B. Mitchell, "The INCH, Discussion and Applications," Solid State Design, v. 3, n. 10, October 1962, p. 34-43.

(2) Blake, R. F., "Static Relays: How Well Do They Work? How Can You Use Them?", Aerospace Electronics, July 1960, p. 143-153.

(3) Brubaker, T. A., "A Non-saturating Transistor Switch for Analog/Hybrid Instrumentation and Computers," University of Arizona, Department of Electrical Engineering ACL Memo No. 78, May 1963 (N63 23058).

(4) Gofman, S. A., L. P. Olomutskii, A. N. Karmodonov, and M. S. Roitman, "Zero Stability of Synchronous Detectors with Semiconductor Diodes and Triodes," Electrical Measurements (English translation of Izmeritel'naya Tekhnika), September 1961, p. 718-722.

(5) Gregory, R., "Spiking Switching Spikes in a Chopper Amplifier," Electronic Design, 25 May 1964, p. 42-45

(6) Kalafian, M. V., "Transistor Bridge Switches Microvolts," Electronics, 3 January 1964, p. 60.

(7) Kharchenko, R. R., and V. N. Malinovskii, "Diode Switching Circuits for Measuring Purposes," Electrical Measurements (English translation of Izmeritel'naya Tekhnika), August 1961, p. 626-633.

(8) Korn, G. A., "The Impact of Hybrid Analog-Digital Techniques on the Analog Computer Art," Proceedings of the IRE, v. 50, n. 5, May 1962, p. 1077-1086.

(9) Millman, J., and T. H. Puckett, "Accurate Linear Bidirectional Diode Gates," Proceedings of the IRE, v. 43, January 1955, p. 29-37.

(10) Roy, R., "Transistorized High Frequency Chopper Design," Electronic Design, 6 August 1958, p. 41-44.

(11) Smith, A. B., "Transistor Switches for Low-Level Signals," Electro-Technology, v. 69, n. 2, February 1962, p. 202-204.

(12) Solbakken, A., "Design of High-Speed Electronic Switches," M.I.T., Electronic Systems Laboratory Memo No. 3, DSR 8823, 11 January 1963.

The following circuits have been tentatively selected for further analysis and possible breadboard evaluation:

(a) a modified version of the Guennou chopper (see diagram below);

(b) a nonsaturating transistor switch (see Reference 3 above);

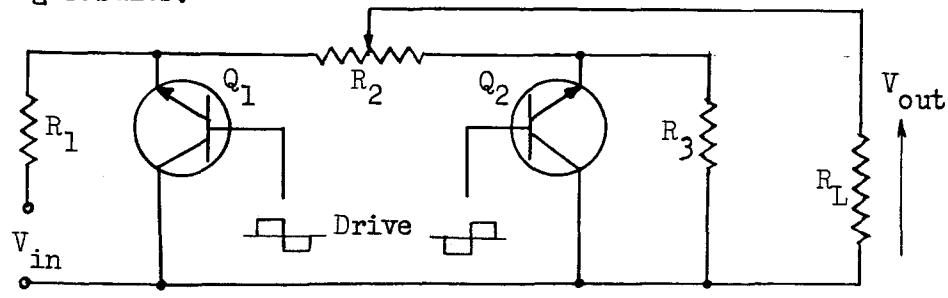
(c) a microvolt transistor bridge (see Reference 6 above);

(d) a field-effect transistor switch;

(e) a six-diode bridge using improved diodes (see Reference 9 above);

(f) a photoconductor switch.

Preliminary laboratory experiments have been performed with the modified, direct-coupled, Guennou chopper circuit depicted below. This version of the circuit appears suitable for non-repetitive switching applications, as in the area of analog computer programming of interest under the contract. Tests have been made to determine variations in offset voltage, feedthrough, leakage, and gain with various settings of load resistance (R_L), balance pot (R_2), and shunt resistance (R_1,R_3) for the case of either randomly selected transistors or transistors matched as regards drive current for minimum offset voltage. Thus far, only type 2N697 transistors have been tried, and the results seemed little better than those obtainable with the simplest single transistor switch. However, improvements in the present method of matching transistors and the use of other transistor types for this circuit may yield more promising results.



During the coming quarter, greater attention will be given to the six-diode bridge circuit (item e above), as suggested by Dr. Polstorff in his letter of 15 May and further discussed in the conference on 5 June.

GROUP 2 PROGRESS REPORT

Current Activities

In the preceding quarterly report, two major areas of investigation were identified under Task C of the contract, namely: Area 1 - the development of a synthesis technique for constructing an analog computer circuit which will operate on Gaussian white noise to produce an output process with prescribed first and second moments, and Area 2 - a consideration of the problems associated with processing random signals to determine their moments and other useful statistical properties. During the present report period, the work identified as Area 1 and certain aspects of Area 2 were completed. A Technical Note describing this work is being prepared for publication in the next report period.

The Technical Note is to include sections on (a) the synthesis procedure for constructing analog computer circuits to generate nonstationary random processes from stationary noise inputs, (b) the instrumentation required to measure the parameters of nonstationary random processes produced by the computer, and (c) examples of the use of the synthesis procedure and the instrumentation. This material may be briefly outlined as follows.

The synthesis procedure makes possible the design of a computer circuit which accepts as its input a Gaussian stationary process with constant power spectral density and produces as its output a nonstationary process with prescribed first and second moments. The first moment or mean of the random process can be generated separately and incorporated with the final output process in a straightforward way. Therefore, the major part of the synthesis procedure applies to generating a random process with zero mean and prescribed second moment or covariance.

This latter procedure involves the following four steps. (1) Approximate the prescribed covariance function with a series expansion. (2) Write a general differential equation for the linear time-varying operation to be performed by the computer on the stationary noise input as

$$L_t \{x(t)\} = N_t \{y(t)\}$$

where x(t) is the desired output random process, y(t) is the stationary white noise input, and L_t and N_t are linear differential operators. (3) Use a technique, which will be described in detail in the Technical Note, to determine L_t and N_t from the expansion of the given covariance function. (4) Synthesize a computer circuit from the differential equation of step 2. The number of multipliers in the resulting computer circuit will be proportional to the number of terms necessary for a good series approximation to the covariance function in step 1.

A procedure for sampling nonstationary noise processes generated on the computer, recording the samples on paper tape, and processing the recorded results with a general purpose digital computer has been developed and will be described in the Technical Note.

Plans for Next Quarter

Group 2 efforts will be expanded during the summer quarter with the following personnel assignments:

Dr. D. L. Finn, Professor of E.E. (one-half time)
Dr. J. L. Hammond, Jr., Associate Professor of E.E. (one-half time)
Dr. R. P. Webb, Assistant Professor of E.E. (one-third time)
Dr. T. M. White, Associate Professor of E.E. (full time)
Mr. R. E. Bryan, Graduate Research Assistant (full time)
Mr. J. S. Gray, Graduate Assistant (one-half time)
Mr. J. W. Petway, Graduate Assistant (one-half time)
Mr. J. H. Schlag, Graduate Assistant (one-half time)

As indicated earlier, work in Area 1 is essentially completed. Efforts during the next report period will be devoted to Area 2 and a new area, which will be identified as Area 3 - Hybrid Computation, to be added by the Sponsor to Task C.

Planned activities for the next report period include the following:

(a) Completion of a Technical Note
(b) Measurement of Nonstationary Random Processes - This will include work directed toward processing measured data on covariance functions to obtain series expansions appropriate for use with the synthesis procedure developed under Area 1, and work relating to statistical accuracy of measurement and sensitivity of results to small changes in measured data.

(c) Properties and Representations of Nonstationary Random Processes - A study of the best representations for nonstationary random processes, properties of nonstationary processes which violate common assumptions made for stationary processes, effects of nonstationary processes on physical devices, and related topics.

(d) Problems in Hybrid Computation - An attempt will be made to formulate several approaches to problems in hybrid computation. The first problem to be considered is that of determining a criterion for the necessary speed of a digital computer to be used with an analog computer in solving a given class of problems. Consideration is being given to two approaches, one involving a statistical performance criterion, and the other being an attempt to obtain useful deterministic bounds on the complexity of possible output analog signals so that sampling rates for a given accuracy can be specified.